The Vertebrate Circulatory System

Transportation

Respiratory
Erythrocytes (red blood cells) transport oxygen from lungs to tissues
Hemoglobin of red blood cells is transporter
CO₂ is released by cells into blood - carried back to lungs

Nutritive
Nutrients enter blood through wall of intestine
Carried to liver and to all body cells

Excretory
Metabolic wastes carried to kidney for removal
Filtered through capillaries - Excreted in urine

Regulation

Hormone transport
Hormones produced in endocrine glands - transported to target tissues throughout body

Temperature regulation
Warm-blooded vertebrates are homeotherms
Heat distributed by circulating blood
Temperature adjusted by directing flow to or from extremities

Protection

Blood clotting
Protects against blood loss when vessels are damaged
Involves proteins in plasma and platelets

Immune defense
Leukocytes, white blood cells, provide immunity against disease agents
Are phagocytic, produce antibodies or have other actions
**Blood Vessels**

Arteries - carry blood away from heart

Arterioles - network of microscopic vessels of arterial tree

Capillaries - fine network of thin-walled tubes

Venules - small vessels that collect blood from capillaries

Veins - return blood to heart

Arteries, arterioles, veins and venules have similar structure

- four layers of tissue: endothelium, elastic fibers, smooth muscle, connective tissue
- too thick to permit exchange of materials with surrounding tissues

Exchange with tissues occurs in capillaries, endothelium is only layer molecules and ions leave blood plasma by filtration (pressurized) travel through pores in capillary walls or transported through endothelial cells

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**Arteries and Arterioles**

- elastic fibers allow large arteries to expand and recoil when receiving blood from heart - helps to buffer effect of pulsing on capillary beds
- smaller arteries and arterioles are less elastic, but have thicker smooth muscle - allows change in diameter
- small diameter arteries and arterioles cause greatest resistance to blood flow

**Vasoconstriction** - through contraction of smooth muscle increases resistance, decreases flow volume

**Vasodilation** - through relaxation of smooth muscle decreases resistance, increases flow volume
Blood around some organs regulated by precapillary sphincters rings of smooth muscle around arterioles at capillary bed can regulate or stop blood flow to capillary bed.

Example - close beds in skin to limit heat loss in cold environments.

High tissue perfusion

Low tissue perfusion

**Capillary Exchange**

Heart provides sufficient pressure to pump against resistance of arterial tree and into capillaries.

Every cell is within 100 µm of a capillary.

Average capillary 1 mm long, 8 µm diameter, slightly larger than a red blood cell.

Capillaries have greatest cross-sectional area.

Blood velocity decreases in capillary beds.

Provides greater time for exchange of materials with tissues.

Blood pressure is greatly reduced when blood enters veins.
**Venules and Veins**

Veins and venules have thinner layer of smooth muscle than arteries; pressure one-tenth that of arteries; can expand to hold greater quantities - most blood in body is in veins.

- Venous pressure is insufficient to return blood to heart from feet - aided by contraction of skeletal muscles.
- One-way venous valves direct flow toward heart.
- Varicose veins - caused by blood pooling in veins when valves fail.

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Circulatory system delivers by diffusion through capillary walls.

- Filtration driven by pressure of blood - supplies cells with nutrients.
- Most fluid returned by osmosis due to concentration of protein in blood.
- High capillary blood pressure causes production of too much interstitial fluid - “edema” - a swelling of tissues in extremities.

- Edema commonly occurs in feet of pregnant women.
- Edema also results when plasma protein concentration is too low.
- May be caused by liver disease or protein malnutrition.
The lymphatic system recovers lost fluid and returns it to blood.
Composition of lymphatic capillaries, lymphatic vessels, lymph nodes
and lymphatic organs like spleen and thymus.
Fluid in tissues diffuses into blind-end lymph capillaries.

Lymph passes into larger vessels.
Lymphatic vessels also contain one-way valves.

Major lymphatic ducts drain into veins on sides of neck.
Lymph fluid movement assisted by movement of muscles.
Some lymph vessels contract rhythmically.
Lymph modified by phagocytic cells in lymph nodes and
lymphatic organs.
**The Heart** - has two pairs of valves
- Atrioventricular (AV) valves lie between atria and ventricles
  - on right side - tricuspid valve
  - on left side - bicuspid or mitral valve
- Semilunar valves lie between ventricles and main arteries
  - right - pulmonary valve
  - left - aortic valve

Right side sends blood to lungs
Left side sends blood to rest of body

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**How the Heart Is Stimulated to Contract**
Caused by transmission of membrane depolarization triggered by **sinoatrial (SA) node** - the “pacemaker”
- SA cells depolarize spontaneously with regular rhythm
- depolarization passes from one cardiac muscle cell to another cardiac cells are “electrically” coupled by gap junctions
- Atria contract first - ventricular depolarization delayed by ~ 0.1 sec
- Separated by nonconductive connective tissue
- Wave passes via **atrioventricular (AV) node**
- Delay permits atria to empty before ventricles contract
Ventricles contract together - signal carried through atroventricular bundle of fibers - “Bundle of His”
Signal transmitted by Purkinje fibers to bottom of ventricles stimulates ventricular cells to contract
Right and left ventricles contract almost simultaneously from bottom to top, emptying ventricles

ECG readings and contraction

ECG

P wave in ECG

QRS wave in ECG

T = Ventricular repolarization

QRS wave
**Blood Pressure and the Baroreceptor Reflex**

Arterial blood pressure depends on two factors
- Cardiac output - how much ventricles pump
- Resistance to flow

Increased blood pressure caused by
- Increased heart rate or blood volume or resistance
  - Vasoconstriction - produces increased resistance to flow

Blood pressure will fall if
- Heart rate slows or blood volume reduced or vasodilation

Baroreceptors are sensitive to changes in arterial blood pressure
- Located in walls of aortic arch and carotid arteries
- Connected to cardiovascular control center in medulla

When baroreceptors detect decrease in blood pressure
- Stimulates an increased heart rate and vasoconstriction of vessels in skin and viscera
- Raises blood pressure

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Baroreceptors act to maintain blood flow to brain with rapid standing

Rapid standing changes venous pressure in lower body, reduces pressure above the heart

Increases volume of blood in lower body
- Reduced return of blood to heart and reduced cardiac output
- Low blood flow to brain can cause light-headedness or fainting

Reflex rapidly increases heart rate, constricts arterioles
Maintains normal blood pressure